A Volcanic Aura: Observing the Magnitude and Impact of Global SO_2 Emissions

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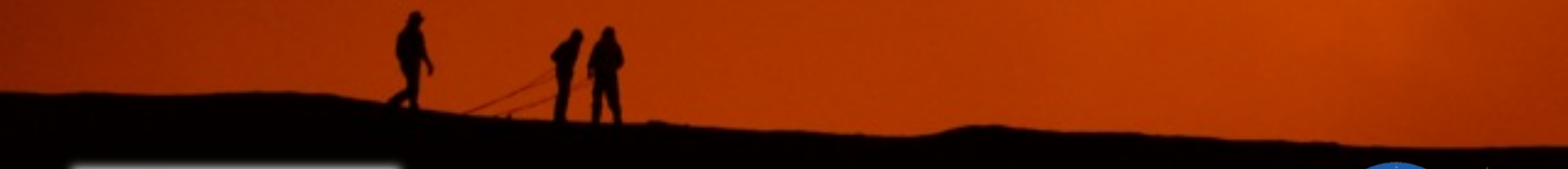
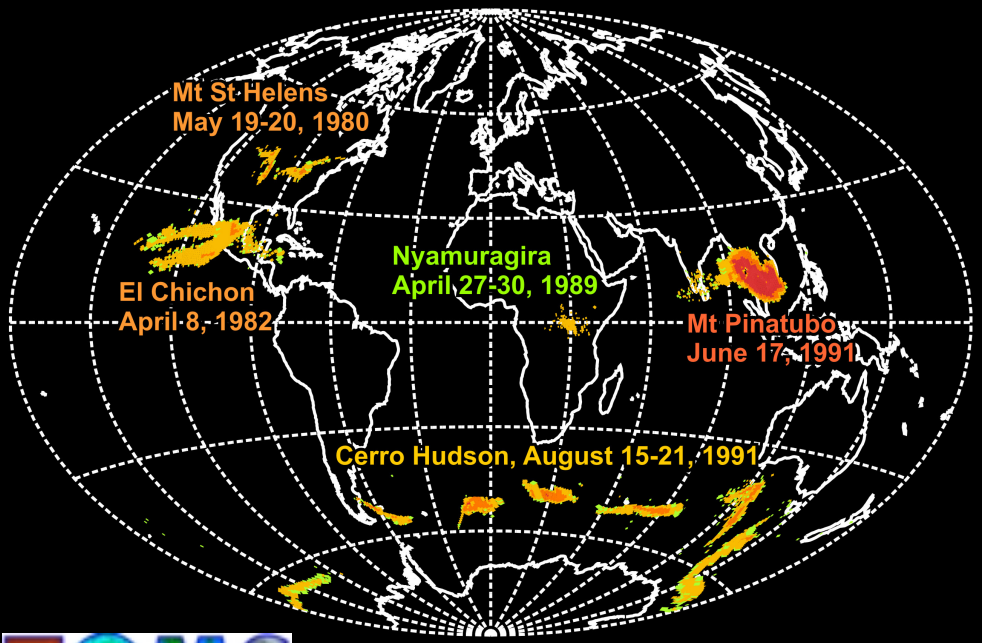


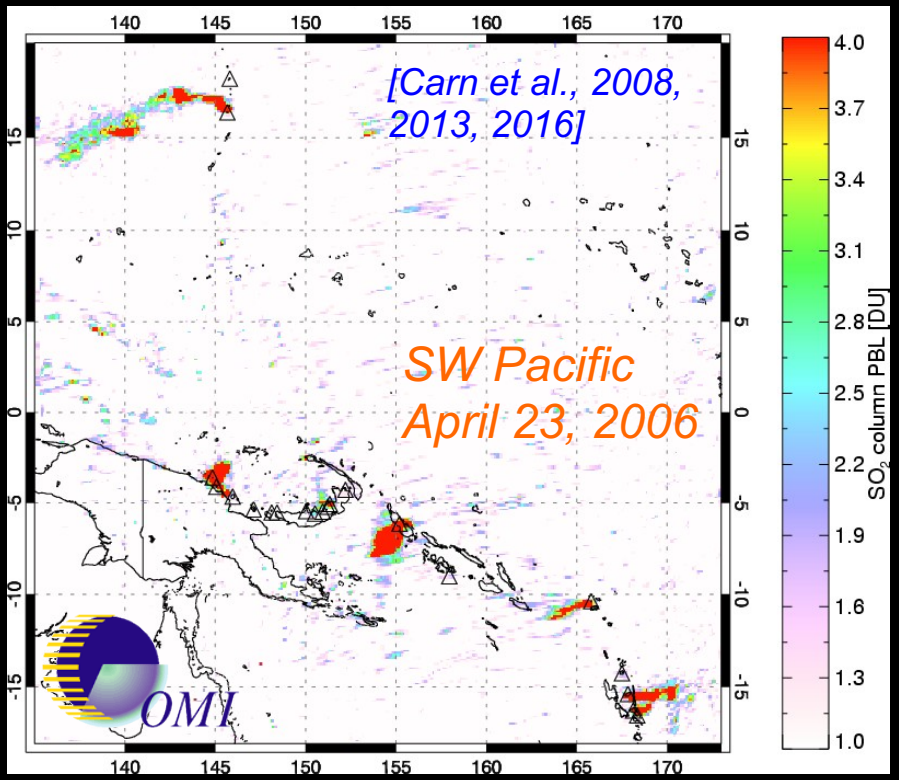
Michigan Technological University

Environment and Climate Change Canada

NASA

UV satellite remote sensing of volcanic SO_2





1978-2005
Total Ozone Mapping Spectrometer (TOMS)

1995-2003
Global Ozone Monitoring Experiment (GOME)

2004-
Ozone Monitoring Instrument (OMI)

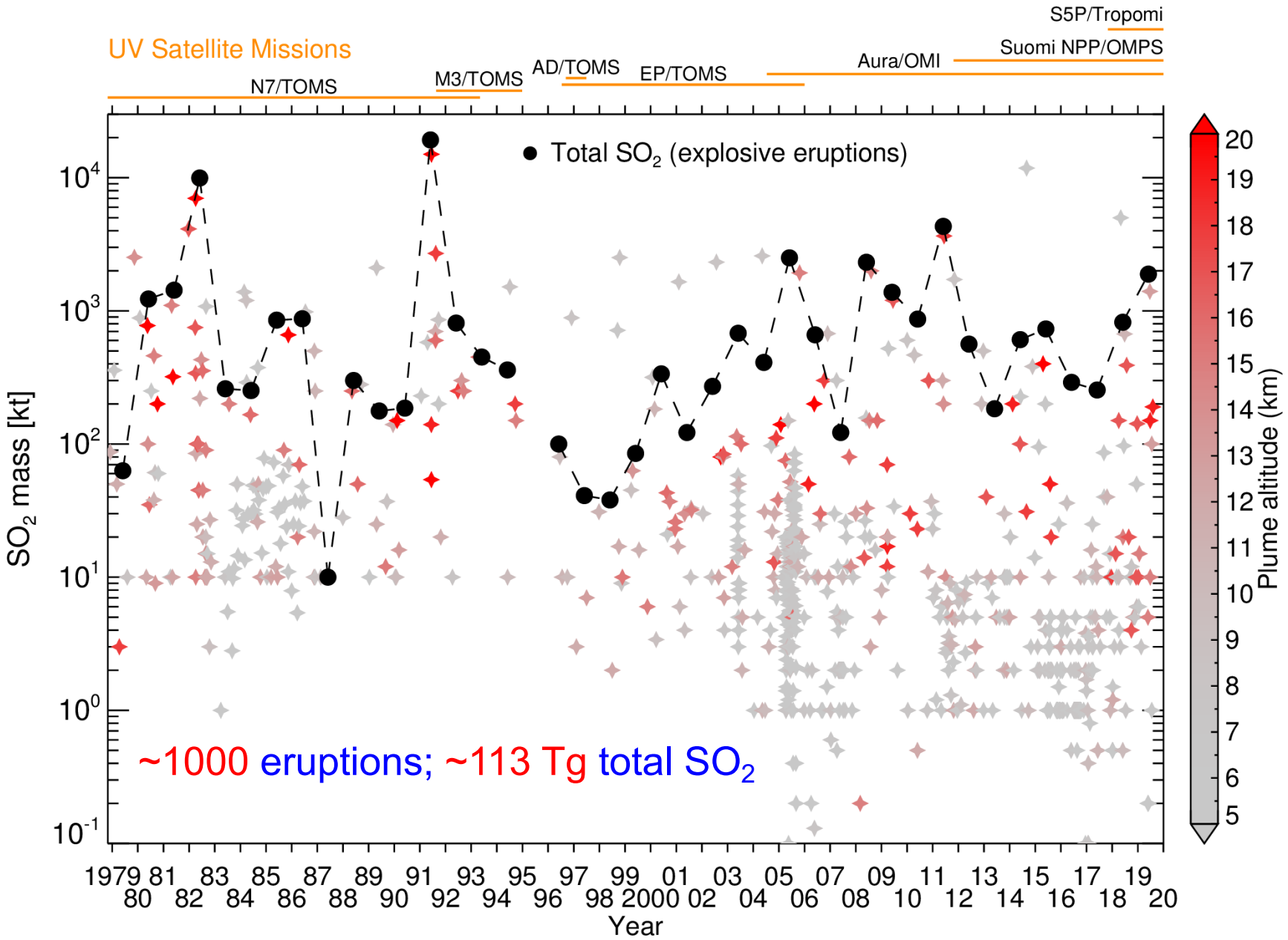
2006-
GOME-2

2012- & 2017-
Ozone Mapping and Profiler Suite (OMPS)

2015-
DSCOVR/ EPIC

2018-
Sentinel 5P TROPOMI

Explosive volcanic SO_2 emissions (1978 – present)



New global volcanic SO_2 emissions inventory

A time-averaged inventory of subaerial volcanic sulfur emissions

R.J. Andres and A.D. Kasgnoc

Institute of Northern Engineering, University of Alaska Fairbanks

[*Andres & Kasgnoc*, JGR, 1998]

- **Volcanic degassing 'source term' in atmospheric chemistry and climate models**
- **Climate impact of tropospheric volcanic emissions (sulfate aerosol)**
- **Estimation of global fluxes of other volcanic gases (e.g., CO_2) and trace metals (e.g., Hg)**

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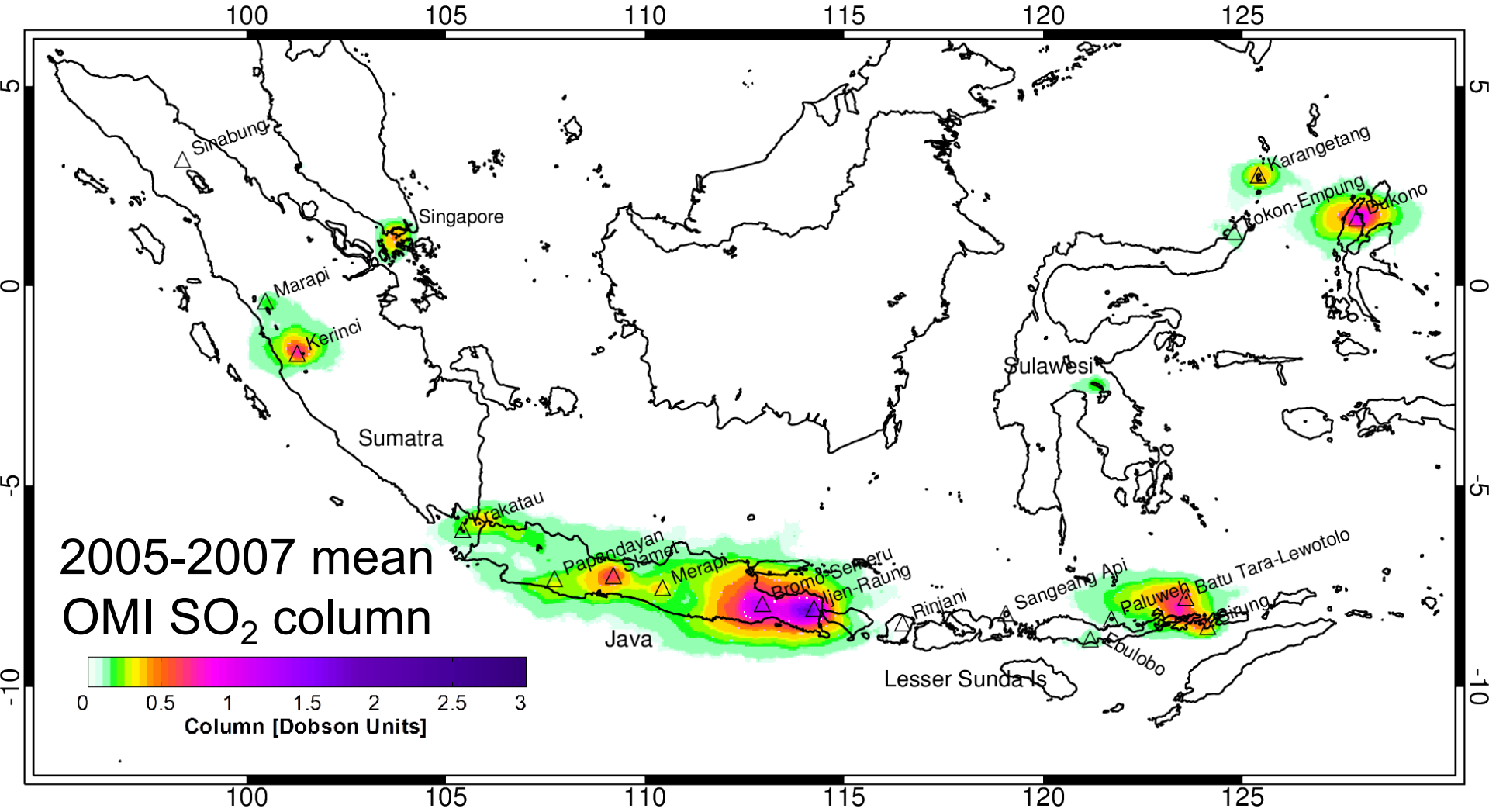
A decade of global volcanic SO_2 emissions measured from space

S. A. Carn[1], V. E. Fioletov[2], C. A. McLinden[2], C. Li[3,4] & N. A. Krotkov[4]

[*Carn et al.*, 2017]
[*Fioletov et al.*, 2016]

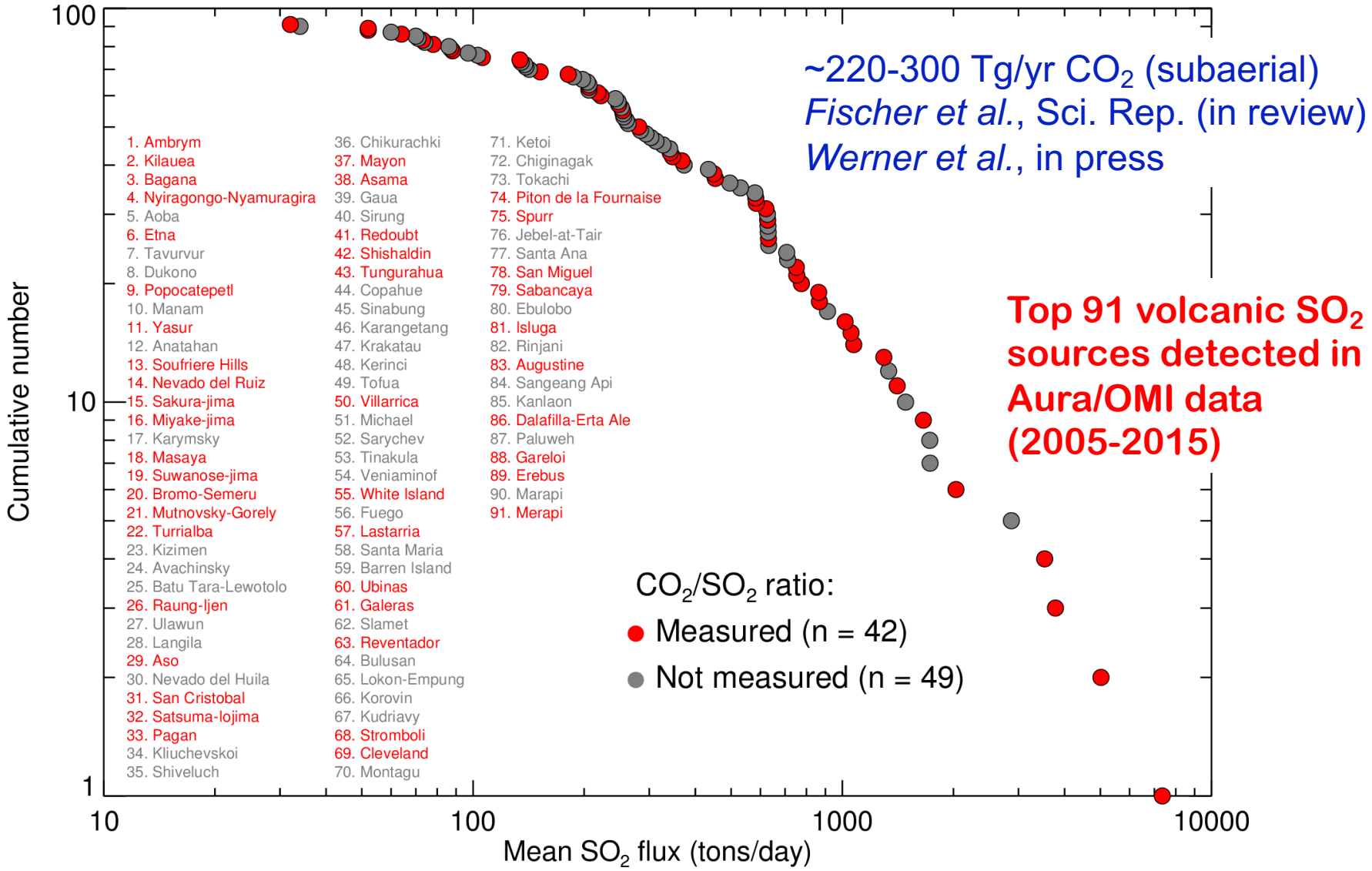
Volcanic SO_2 sources in Indonesia



- **Globally, 90-100 volcanic SO_2 sources quantified (many for the first time)**
- **Total SO_2 flux of 23+/-2 Tg/yr (~63 kt/day)**
- **Volcanic emissions dominate in many regions**

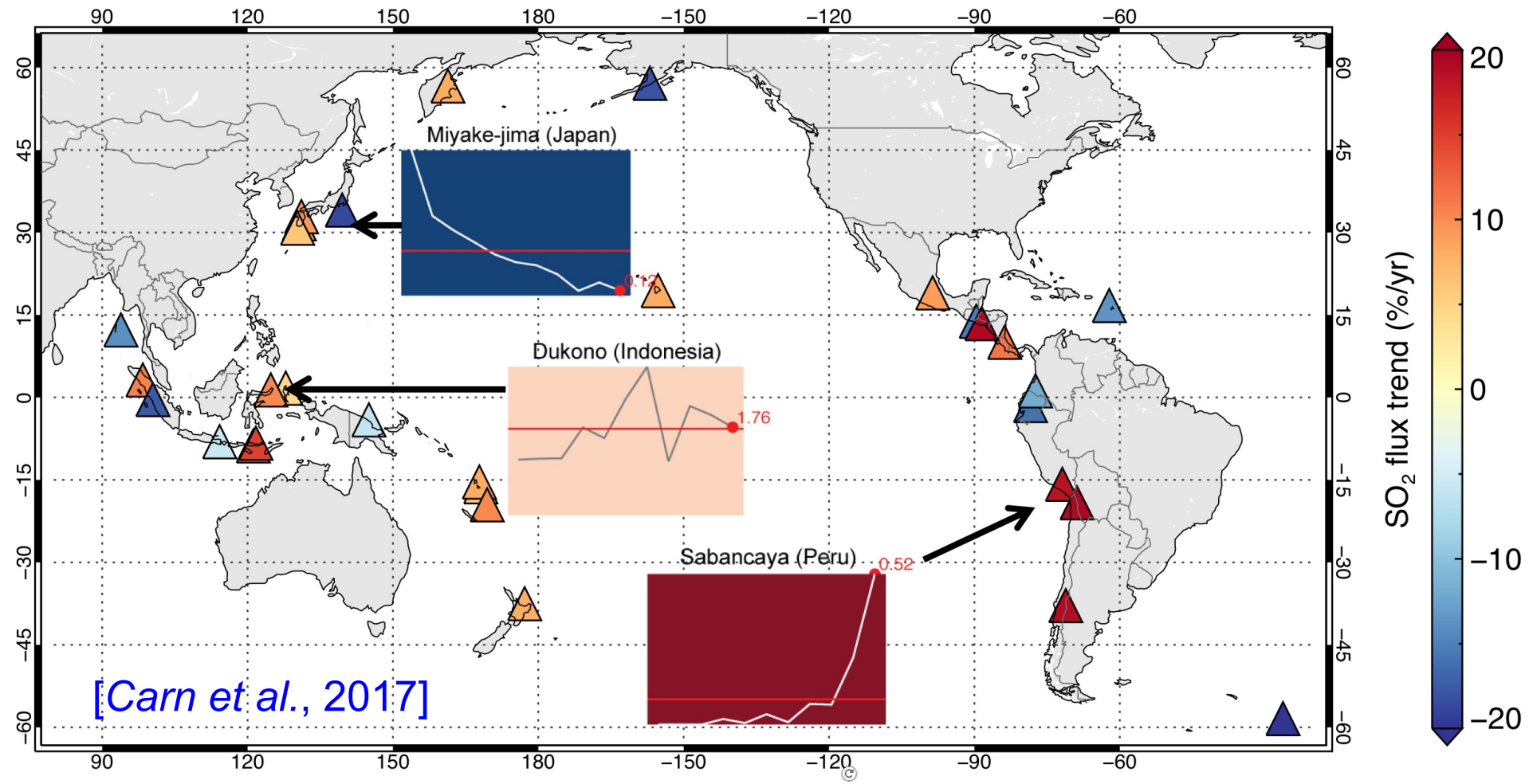
Fioletov et al., 2016
Carn et al., 2017

Improved estimates of volcanic CO_2 emissions



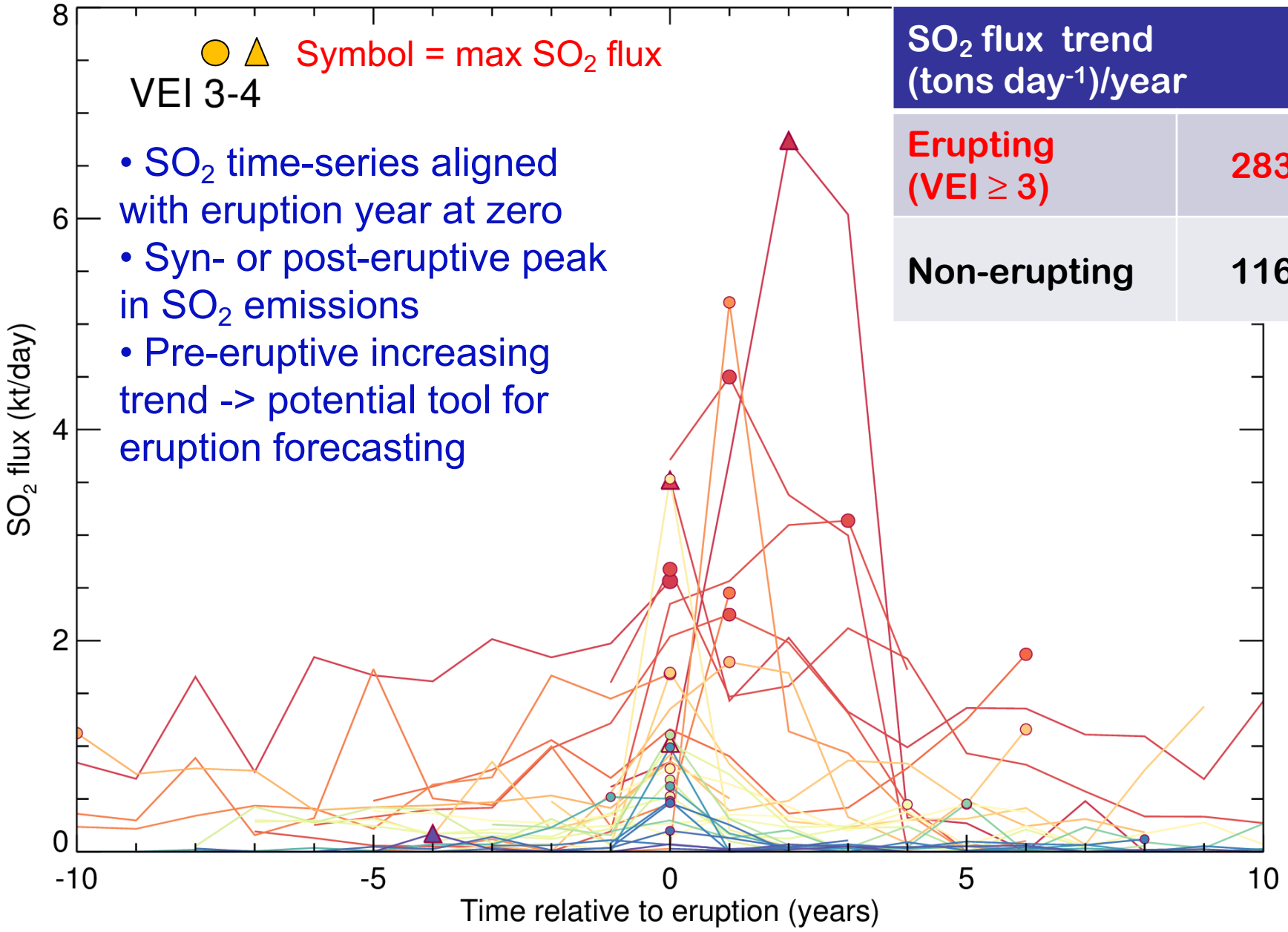
- CO_2/SO_2 ratios measured at many of the strongest SO_2 sources
- ~50% of SO_2 sources still lack CO_2 data – efforts underway to address this

Trends in tropospheric volcanic SO_2 emissions



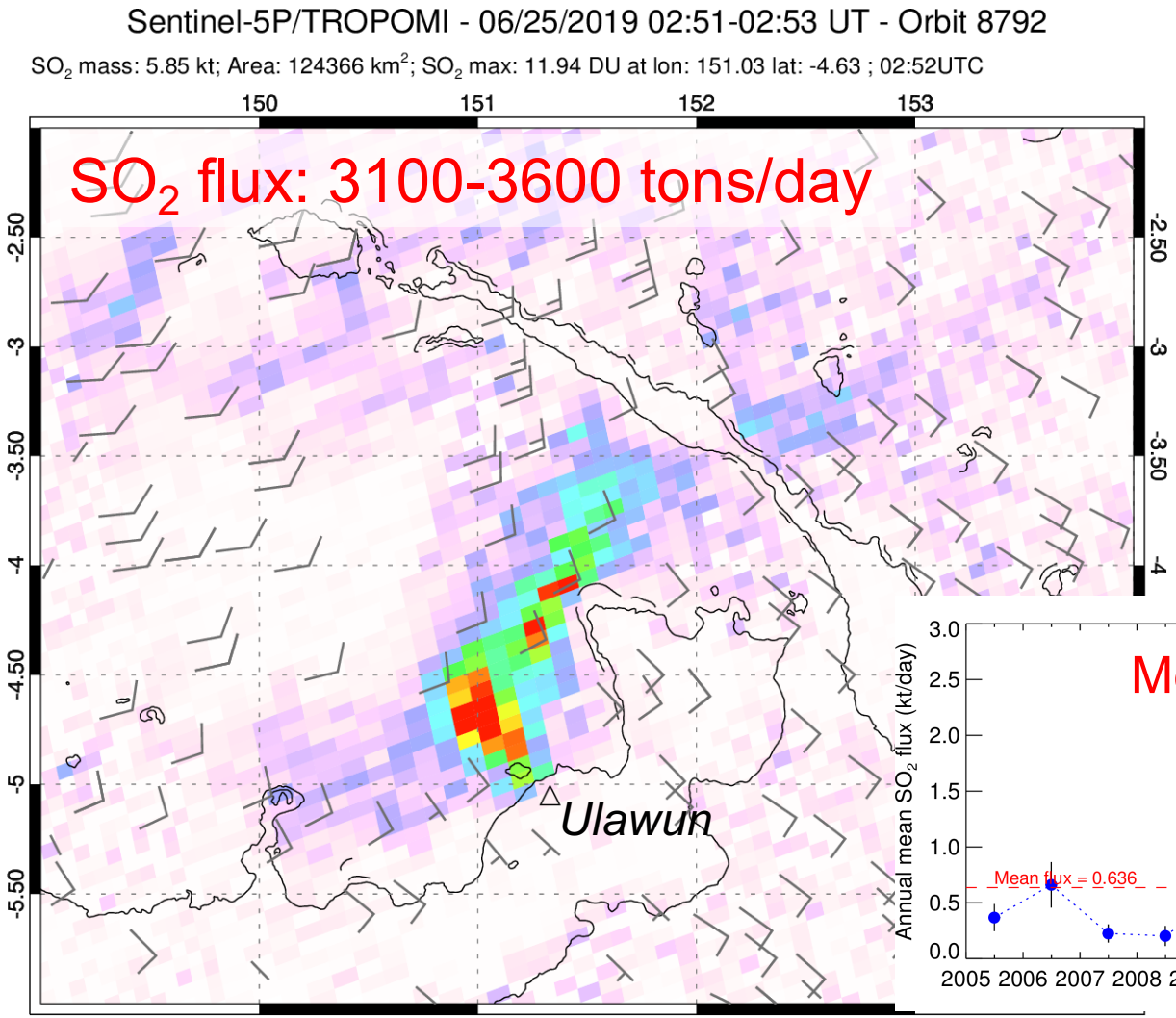
- Aura has captured volcanoes at various stages in their 'life-cycles'
- ~30% of volcanic SO_2 sources show significant +/- trends in emissions
- ~80% of sources also erupted during the decade

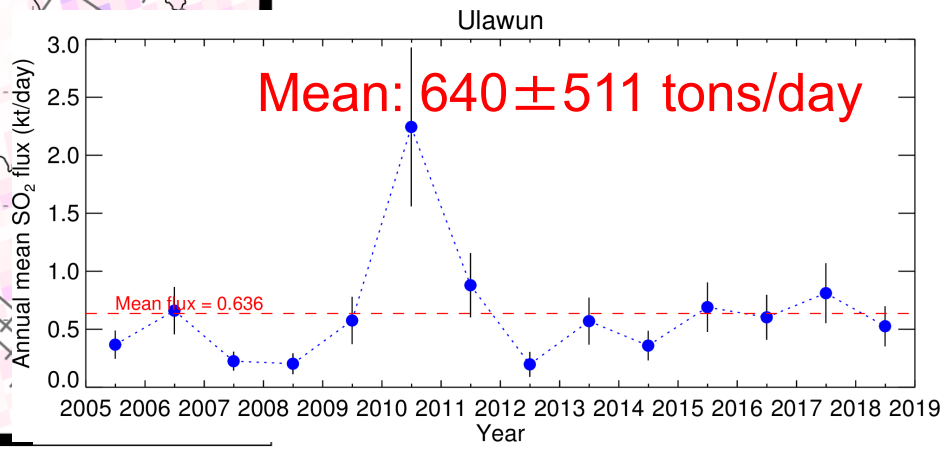
Trends in SO_2 emissions at erupting volcanoes



SO_2 flux trend (tons day^{-1})/year	
Erupting (VEI ≥ 3)	283
Non-erupting	116

Identifying 'pre-eruptive' SO_2 emissions

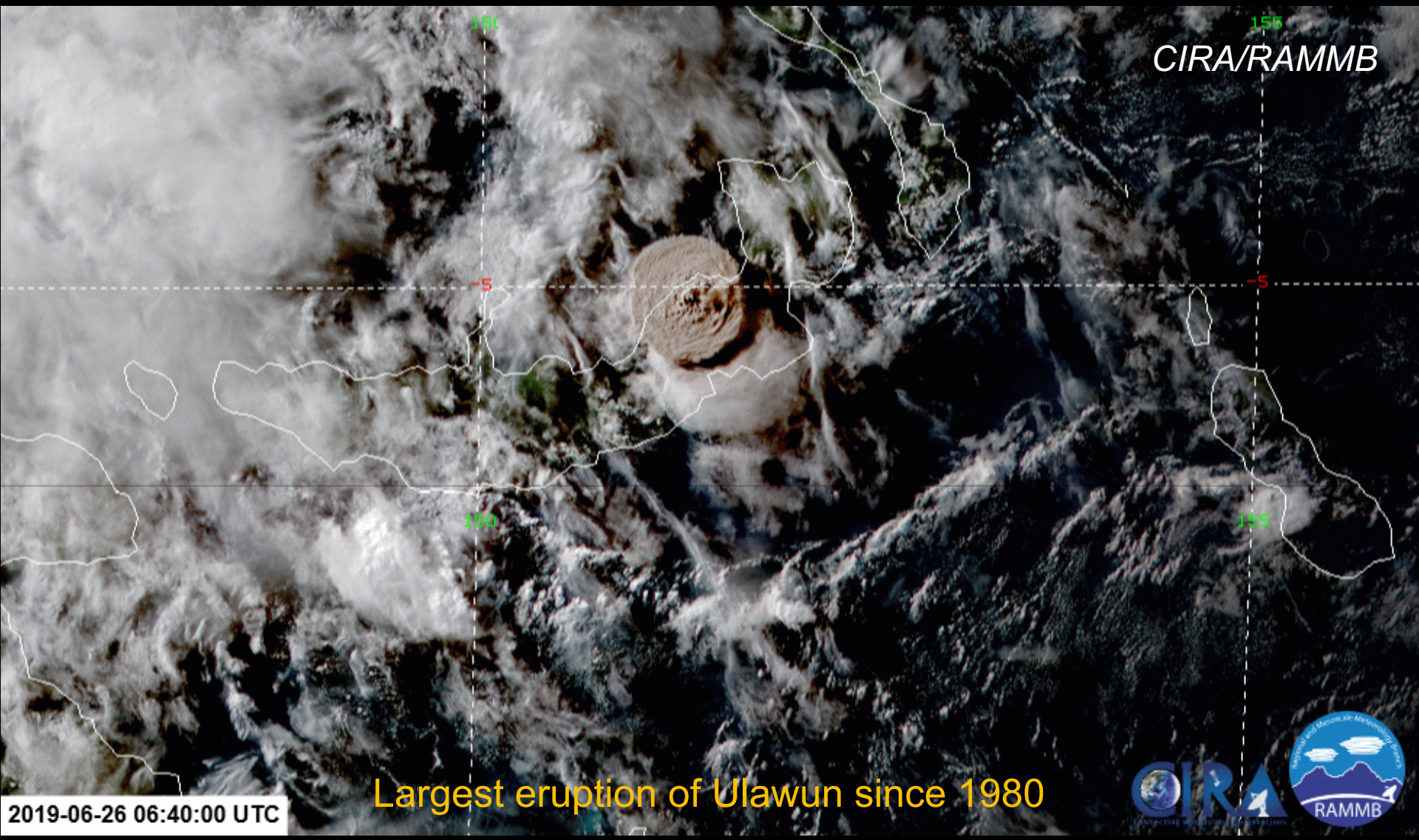




- Long-term Aura/OMI record constrains magnitude of 'typical' volcanic SO_2 emissions
- At Ulawun volcano (PNG), *SO_2 emissions ~5σ above decadal mean measured prior to major eruption on June 26*

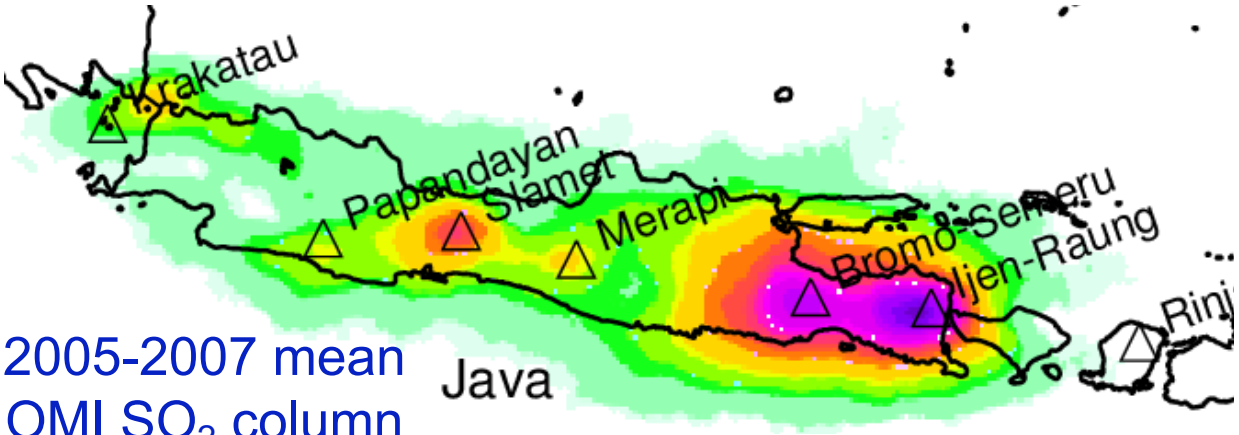
Data: BIRA-IASB/DLR/ESA/EU Copernicus Program

Eruption of Ulawun (Papua New Guinea) – June 26, 2019

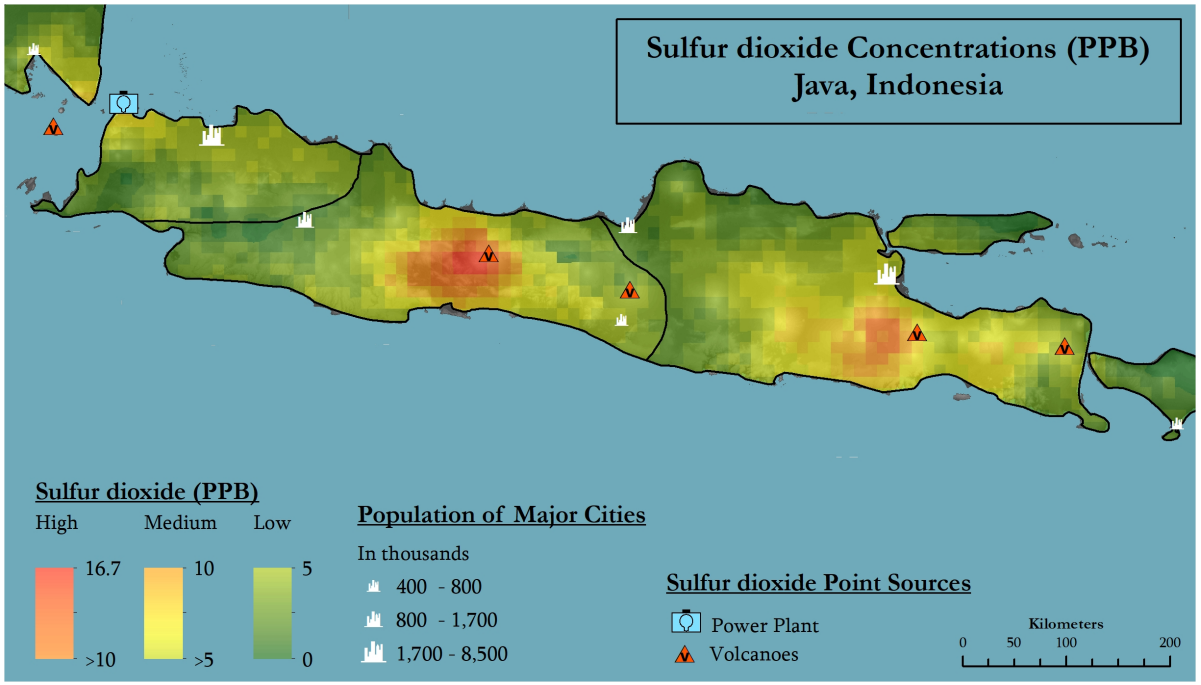


- NASA aims to sample volcanic eruption clouds – need advance warning

Population exposure to volcanic SO_2

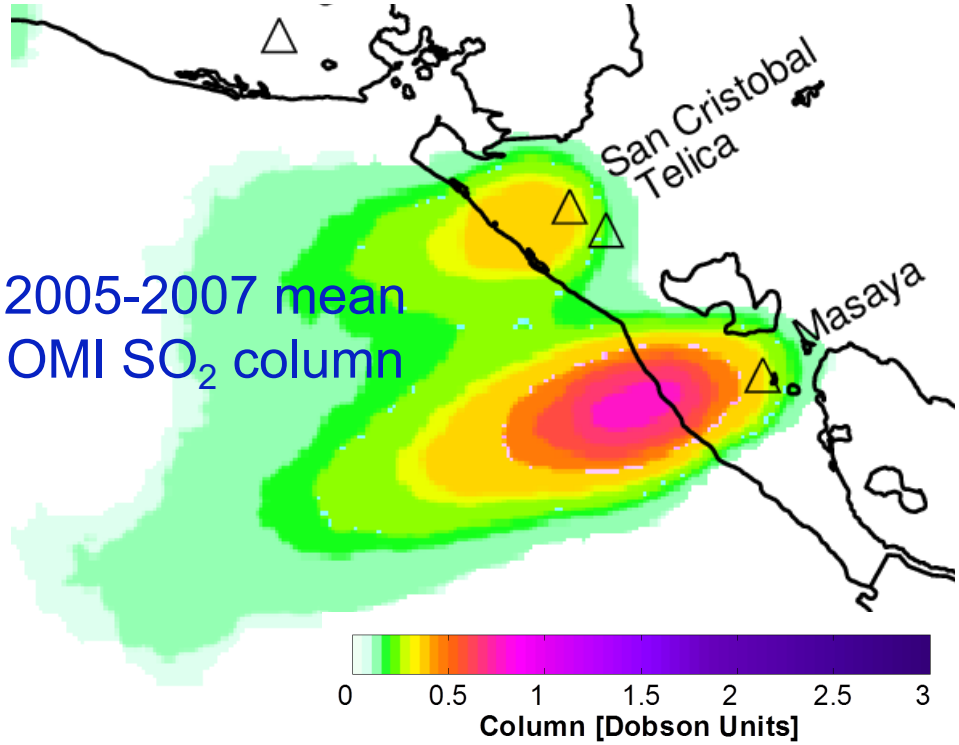


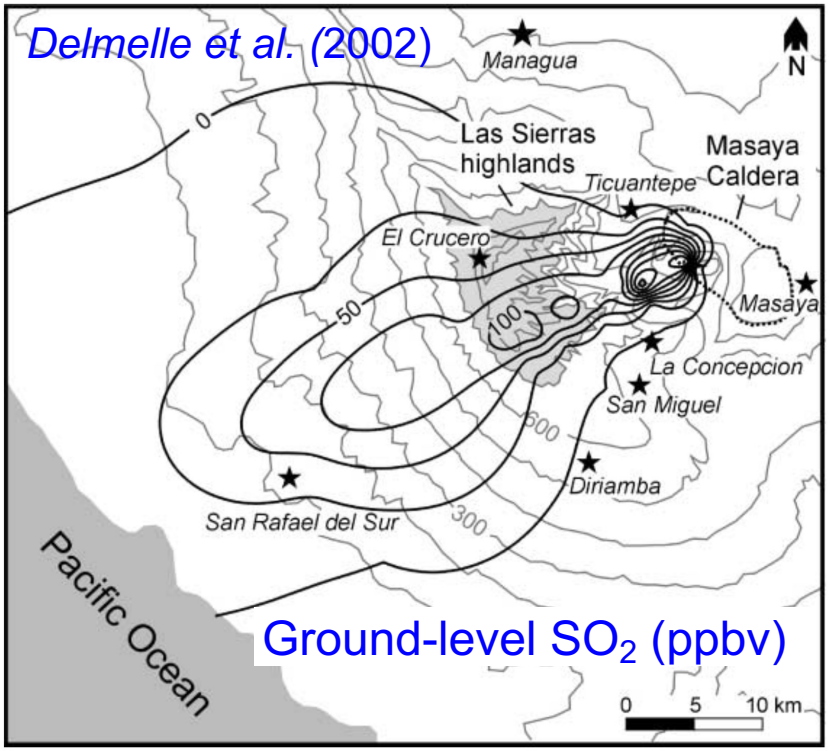
2005-2007 mean OMI SO_2 column



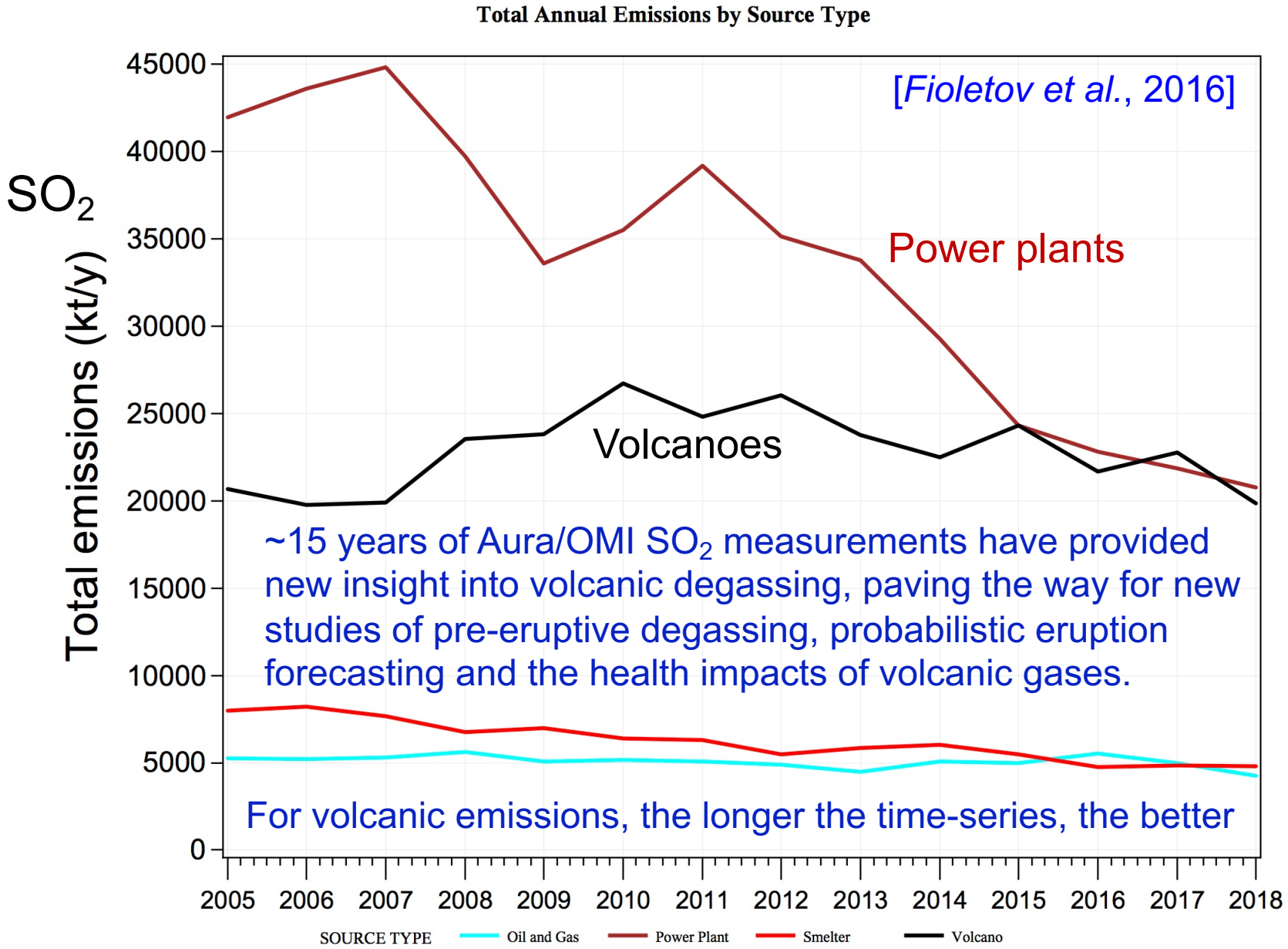
- Satellite & census data permit estimation of population exposure to SO_2 pollution (e.g., *Li et al.*, 2017)
- Exposure to volcanic SO_2 (and other volcanic emissions) is not well constrained and can be a significant, chronic hazard
- Goal: methodology for producing first volcanic gas 'hazard maps'

Volcanic air pollution at Masaya (Nicaragua)





Summary


Total Annual Emissions by Source Type
SO_2
Total emissions (kt/y)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
[Fioletov et al., 2016]
Power plants
Volcanoes
~15 years of Aura/OMI SO_2 measurements have provided new insight into volcanic degassing, paving the way for new studies of pre-eruptive degassing, probabilistic eruption forecasting and the health impacts of volcanic gases.
For volcanic emissions, the longer the time-series, the better
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
SOURCE TYPE
Oil and Gas
Power Plant
Smelter
Volcano